

MINERAL SCIENCE

FOR SCHOOLS—LEADING TO

PHYSICAL GEOGRAPHY, PHYSICS,
CHEMISTRY, USEFUL MINE PRODUCTS,
AND ECONOMIC PROCESSES.

A Study of Inorganic Nature

adapted to

First Lessons in Science.

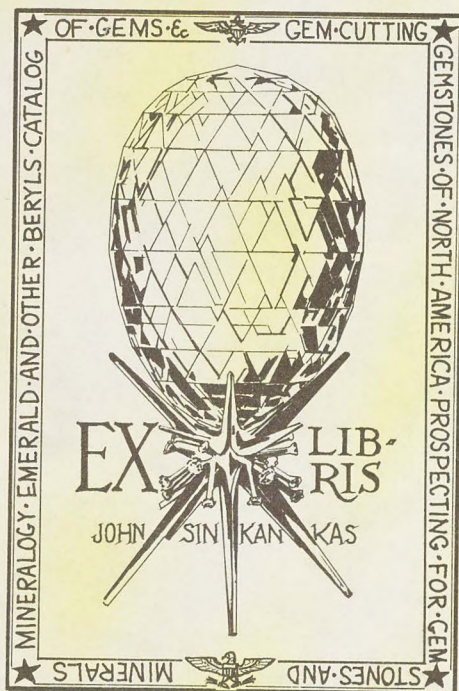
BY MINER H. FADDOCK, A. M.

PROVIDENCE, R. I.

*Author of "Minerals in the Public Schools," "A Pupils' Hand
Book in Minerals," "A Teachers' Key
to Mineral Science."*

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INTENTION OF THE COURSE.

Bearing in mind the close contact sought between science training and practical results, the following plan of daily work during the first year is suggested:

1. For authority on features of the Earth,—(a) the continents, their form, structure; mountain elevations; valley and drainage systems; coast line activities; (b) the oceans—their form, movements, life and effects; (c) the forces and agencies of nature which are daily operating, have caused the present phases of Earth, and are changing these continually, see the adopted textbook on Physical Geography, with recitation two days weekly during the year.

2. As guide to the science of Mineralogy; to the composition of rocks; to knowledge of useful minerals, the metals, and their origin; to the forces of nature at work in the rocks physiographically considered; to economic processes by which the useful products are derived; and as a study of the properties of matter after the manner of Physics, the present manual one day each week with physical or chemical experimentation to illustrate.

3. Physics proper according to the adopted textbook,—the properties of matter; forces in matter, cohesion, etc.; study of gases, liquids, gravitation, electricity, magnetism, phenomena of the air, as usually presented in Physics,—the same closely connected with and growing out of Earth study, one day weekly.

4. Lantern Lectures,—on Earth, its origin astronomically considered; growth of continents, mountains, rivers, glaciers; views of different countries with life and physical features, one day weekly.

5. Stereographs, Underwood Travel System,—physical features and phenomena of the Earth; mines, occupations, industrial processes, etc. In experimental laboratory, observation and description by pupils.

6. Examinations, beside textbook, include note books, minerals, résumé of lectures, and stereographic observations.

Physical properties of matter, chemistry of minerals, economic processes, continue in junior and senior years.

PREFACE.

The Inorganic Kingdom. Propriety of the Study.

Earth Study began with the advent of man. Physical Geography was first enunciated, according to Ovid, by Pythagoras, 500 years before the beginning of the Christian era.* Botany, Zoölogy, Mineralogy, Geology were set forth systematically by Aristotle and his followers 300 years B. C. Archimedes, who lived 250 years B. C., has been called the Father of Physics; while Chemistry developed later.

By the early separation of these from the mother science there has been left for Earth Study as a school science called Physical Geography, a rather uninteresting detail of maps, charts, statement of phenomena with occurrence and recurrences of winds, weather, tides, and physical features quite remote often from the pupil's habitat and possible experiences.

For public schools it is a mistake to differentiate the natural sciences rigidly from the parent, and to carry them independently of their origin. It is better to study the Earth and its gifts to man through the sciences which have sprung from Earth study, and by the correlation of these.

* See "Heroes of Science," by Duncan, S. P. C. K., London. There is, however, best of authority for assigning to Aristotle the teachings attributed to Pythagoras by Ovid. See Tozer's History of Ancient Geography.

For educational school work, we should recognize more fully the important distinction of inorganic and organic nature, and study Earth and the sciences in the two groups arising from this distinction.

In the first group are Physics, Chemistry, the physical features and phenomena of the Earth, while at the basis of these and typically representing the forces and substances of the inorganic world, is the highly educational subkingdom of the minerals. In the second group, obviously, are Botany, Zoölogy, and, broadly, Biology.

In Physical Geography, the inorganic—that is to say the mineral—is indispensable, with a blending of Biology to such extent as we like; in Geology, as is well known, the blending of the organic with the mineral is indispensable.

Minerals the Foundation of Study of Inorganic Nature.

The best phase of inorganic nature, basis of Physical Geography, that can be brought into the schoolroom for contact with pupils' minds, illustrating the workings of nature and the properties of matter, is the minerals. Minerals are intimately related to the structure of the rocks; they show the constitution of matter in mass; they display properties of the molecule relative to form and structure of matter; they exhibit various properties due to varied degrees of force between molecules when in mass called cohesion; and in fact lead to a searching investigation of

all the physics of matter. They are the chemistry of nature; in the rocks they are also the historical records of the forces of nature that have been at work in the crust of the globe.

What more intelligent study or investigation could be brought into the schoolroom? The study is at once the foundation of Physics, of Chemistry, of rocks, utilities derived from the rocks, of Physical Geography and Earth Study.

PART I.
MINERALS;
as a Part of the Study of
PHYSICAL GEOGRAPHY,
and Introductory to Science Study.

The objects appearing in Nature and seen about us are of two kinds:

1. Those formed by the elements without the processes of life.
2. Those occurring through or by life.

The former are Minerals, and are called the *Inorganic Kingdom*. The latter are Plants and Animals, —Botany and Zoölogy,—and are called the *Organic Kingdom*.

While in the study of Physical Geography plants and animals will be properly noticed, in this section we shall consider *Minerals*, their origin and utility and what they teach.

Elements are substances composed of only one kind of matter,—as iron, oxygen, carbon, sulphur.

The atoms of which matter is composed form molecules. Molecules, whether all of one kind of atoms (elements), or of different kinds of atoms (com-

pounds), tend when solid to take on crystal form, and to exhibit other marked and characteristic physical properties.

This in short is the field of inorganic nature,—namely, minerals. That is to say, the field of inorganic nature which we are to study includes the elements and their compounds, and the different properties which these exhibit as found in nature without the processes of life.*

The great body of inorganic nature, however, which we see about us, the rocks and the soil, being in a disintegrated or confused mass, fails to show crystal form and structure, and fails often to exhibit in marked degree or conspicuously the properties of the strictly mineral bodies.

These characteristic products of inorganic nature which we call minerals, with or without the crystal form, are found in the rocks in vast quantities, filling cavities which when opened we call mines. Hence the name mineral, anything taken from a mine.

The mineral, own and exact product of the forces of nature working in the rocks, shows the properties of matter in their perfect manifestation, and to the minerals we must have recourse for *all study of the properties of matter in their most instructive display.*

* The gases of inorganic nature, oxygen, nitrogen, carbon dioxide, etc., belong to the mineral kingdom, as do also the liquids, water, rock oil, etc. Coal, graphite, fossil gum, etc., though once of the organic kingdom, found in the rocks, are classed with minerals.

Minerals then, generally speaking, are chemical elements or compounds formed or found in the rocks. They are the source of the substances which compose our school chemical laboratories, and of our great industrial laboratories in the useful arts. A mine is one of Nature's chemical workshops, which we open, perhaps long ages after it was closed and from it draw our wealth.

Thence come our metals, our gems, our useful and ornamental stones, our various chemical reagents and products that supply the wants of civilized man. Fortunate for us that nature has thus gathered in convenient storehouses the wealth of the rocks, otherwise this would have been forever beyond our reach. A nation is poor, the rocky foundations of whose country furnish no material from which useful products may be derived. And equally poor those who remain ignorant of the wealth beneath the surface.

Minerals, how formed.

Minerals form in the rocks out of the material of the rocks, (a) by fusion, (b) by deposit out of solution with water, (c) by sublimation or deposit from gases, (d) and even by quiet change, as where lava quietly in long ages changes to granite, composed of quartz, feldspar and mica.

Mineral material draws itself together into cavities in the rocks, sometimes forcing the rocky layers apart to make the cavities. This power which mineral ma-

terial of one and the same kind has of drawing together in the rocks is called segregation.

The structure of the mineral shows its manner of formation, and this indicates the forces at work in the rocks. Thus,—the crystallized structure of marble indicates heat and pressure of metamorphosis; the crystalline structure of calc-spar, and the varied coloring of agate indicate deposit from solution. A molten mass (volcanic), cooling rapidly or slowly, may become finely or coarsely crystallized; a sedimentary rock may become crystallized by metamorphosis, with mineral masses collected in cavities; and waters and vapors loaded with mineral substances, entering neighboring rocks, may deposit mineral formations. Mineral material, as gypsum or halite, lying in extensive beds, may indicate ancient interior drainage areas.

And so the study of minerals as to their mode of formation leads to knowledge of physiographic history of the Earth in past ages and the growth of our continent. Thus it is seen that minerals, while introducing the study of Physics and physical properties of matter, of Chemistry and chemical properties, are an important aid to Earth study as a whole,—that is to say, to Physical Geography, and are the foundation of a knowledge of the rocks.

Since the pupil comes into direct contact with Nature,—observes, compares, judges, describes,—the study thus pursued reinforces the correct method of mental training.

A TEACHERS' BRIEF

MINERALOGICAL COURSE

BASED ON

Educational Value and Availability, and Sequence of Topics for
Grade Work.

I. A CARBON GROUP.—(Charcoal, carbon dioxide), graphite, coal, calcite, diamond.

II. A SULPHUR GROUP.—Sulphur, (sulphur dioxide), gypsum, galena, pyrite; (study here also halite, hematite, etc.).

III. A QUARTZ GROUP.—Quartz, feldspar, mica, hornblende.

IV. A ROCK GROUP.—Rocks of various kinds; (metals here if desired).

The above mentioned refer to familiar objects and useful ores, and are sufficiently comprehensive for a complete school course. They include the minerals generally studied, regrouped to get progression and sequence.

The course, in each instance, begins with easy experimentation, and proceeds by simple steps to the less well known minerals, and to the physiographic

and rock building minerals,—to calcite of group I., to gypsum, pyrite and hematite of II., and to the entire 3d and 4th groups.

If desired, put additional carbonates with group I.; any other sulphides and sulphates, with also for convenience, chlorides, oxides, etc., in group II.; and silicates with group III. See following analyses for kinds of each,—for instances, of calcite, of quartz, of feldspar, etc.

THE MINERALOGIST'S TECHNICAL CLASSIFICATION,

BASED ON

CHEMICAL ANALYSIS AND RELATIONS.

I. NATIVE ELEMENTS.

NON-METALS.—Graphite, diamond, sulphur.

METALS.—Copper, gold, silver, etc.

II. BINARY COMPOUNDS.

ACIDIC.—Quartz (*anhydrous*).

BASIC.—(Various binary ores, generally basic in their action.) *Oxides*.—Hematite, magnetite, corundum, zincite. *Sulphides*.—Galena, sphalerite, pyrite. *Chloride*.—Halite. *Fluorides*.—Fluorite, cryolite.

III. TERNARY COMPOUNDS—OXYGEN-SALTS.

CARBONATES.—Calcite (*anhydrous*); azurite, malachite (*hydrous*).

SULPHATE.—Gypsum (*hydrous*).

PHOSPHATE.—Apatite.

SILICATES.—Steatite (*hydrous*); topaz (*subsilicate*); mica (*unisilicate, hydrous*); feldspar (*unisilicate, anhydrous*); hornblende, (*bi-silicate*).

IV. HYDROCARBONS.

Coal,—anthracite, bituminous, cannel; (also asphaltum, amber, fossil gums).

An element,—sulphur, gold, etc., when found in nature as a mineral is classed as a *native* element. The metals are easily recognized; those not metals are called non-metals.

When two elements unite, they constitute a *binary* compound; binary means two, or of the second order. The non-metal binaries are chemically acidic, i. e., make acids; the metals are generally basic,—an opposite chemical quality to the acidic. The non-metal binary compounds, carbon dioxide and sulphur dioxide (and hydrogen sulphide) are gaseous, and active mineralizers; silicon dioxide on the other hand is a solid but a mineralizer.

Ternary means third or third order,—refers to the union of bases and acids to form salts, or ternary compounds.

Hydrous means that the mineral has water in its composition; anhydrous has not.

PROPERTIES OF MINERALS.

I. PHYSICAL.

You learn from examination of the minerals that they may have the following properties:

- | | |
|---------------|-------------------|
| 1. Hardness. | 8. Streak. |
| 2. Form. | 9. Lustre. |
| 3. Structure. | 10. Diaphaneity.* |
| 4. Cleavage. | 11. Touch. |
| 5. Fracture. | 12. Magnetism. |
| 6. Tenacity. | 13. Electricity. |
| 7. Color. | 14. Weight. |

What belongs to a person or thing we may call a property of that person or thing; hence we may call these qualities properties of the minerals.

Beside the above, which are physical, there are also, as we shall see later, chemical properties. The difference between a physical and a chemical property will be apparent later.

It will be a part of your study to observe how minerals exhibit these different properties, and how one

* The term, transparency, may be used.

mineral will show a certain property more strongly than another will, or in a different way entirely. Then you will pick out those strong characteristics by which you will know the mineral. You will beside come to understand the uses and natural history of the mineral.

I. **HARDNESS.** One can easily make a list of minerals increasing in hardness regularly from softest to hardest. The following is one commonly employed with which to compare other minerals.

Student's Scale of Hardness.

1. *Stearite*, scratches easily with the finger nail.
2. *Gypsum*, scratches difficultly with the finger nail.
3. *Calcite*, scratches with point of pin.
4. *Fluorite*, scratches easily with point of knife.
5. *Apatite*, scratches difficultly with knife.
6. *Feldspar*, scratches with point of file.
7. *Quartz*, too hard for file; scratches with No. 8.
8. *Topaz*, too hard for quartz; scratches with No. 9.
9. *Corundum*, scratches with
10. *Diamond*.

Test hardness on an unweathered surface, where the result will not mar the specimen. Use point of knife or file, educating the hand to determine the degree of hardness by the amount of force requisite to produce a fine cut or scratch.

Make a definition in your own words for hardness and compare it with this: Hardness is the resistance to displacement from position which the molecules of a body offer. (Be careful not to include some other property in your definition, such as toughness or brittleness.) What is meant by a molecule, and what causes the resistance?*

If you have a white mineral of hardness about 7, what white minerals do you know this is not? You have a black mineral of hardness 3, what black minerals can this not be?†

II. FORM. Look carefully at your specimen. Is the outer surface the same as it was in the first place, or has the mineral been broken apart, and a new surface been formed?

1. *Massive* Form. When the original exterior is, or was, irregular, the specimen is *massive*.

2. *Crystal* Form. Do you find smooth flat surfaces on your specimen which are always at certain fixed angles with one another? And is this the original form? If so, then the specimen is a *crystal*.

The pupil will examine crystals belonging to the school collection.

Did you ever see water which contained all the salt it could dissolve, dry completely away? What were formed? Of what shape were the crystals?

* Further developed in the Physics period.

† Worked out in experimental period.

Make a saturated solution of alum; suspend a string in it. Let it evaporate. What forms on the string? What is its shape? What causes the crystals to form? See how large crystals you can make, adding carefully more strong solution from time to time.

III. STRUCTURE. This refers to the interior arrangement of the mineral, and is seen when the mineral has been broken through. Is the broken surface rough and irregular, or is it smooth and flat?

1. *Amorphous* Structure. When the surface produced by breaking is irregular, the structure is *amorphous*.

2. *Crystalline* Structure. When the mineral breaks with smooth faces, or planes, parallel to one another, the structure is *crystalline*, and this method of breaking is called cleavage. Modifications of crystalline structure may be foliated, radiated, fibrous, etc.

3. *Crystallized* Structure. When the interior seems to be composed of fine crystals firmly held together, the specimen has *crystallized* structure, as is seen in true marble. A modified form is granular.

NOTE. A mineral has both form and structure. Thus,—it may be massive amorphous, irregular without and within, as limestone and flint. It may be massive crystalline, as calc-spar;* massive crystallized, as marble. It may be crystal crystalline, as galena and fluorite crystals. Observe the cubical crystal of fluorite has octahedral cleavage.

* Probably all crystalline material would naturally have crystal surfaces if conditions permitted.

Can you see that the arrangement of the molecules produces these differences of structure as well as of form? Does crystalline structure show the material was once in solution? Have you ever seen a pile of bricks arranged end to end in an orderly manner, row upon row, and tier in front of tier? The sides and ends of this pile are even. You may separate the tiers with the hands, and one tier may fall away, leaving the standing tiers still even.

This separation illustrates cleavage, and the arrangement represents crystalline structure. But if the bricks are thrown together promiscuously, can you separate them in the same manner? This represents what kind of structure?

IV. CLEAVAGE. You can now easily define cleavage. Do not forget the separation must be with parallel faces.

A. FORMS. Cleavage may take place in one or more directions and different forms result.

(a) *Basal* Cleavage. If the mineral has only one cleavage face, that one will be the base, and the cleavage parallel to this will be called *basal*; as in topaz, steatite.

(b) *Prismatic* Cleavage. The mineral may cleave in two or more directions, so as to make a prismatic form; as in feldspar, hornblende. (It is not necessary that the ends be perfect.)

(c) *Cubic* Cleavage. It may cleave in three directions so as to make a cube; as in galena, halite.

(d) *Rhombohedral* Cleavage. It may make a rhombohedron; as in calcite.

(e) *Octahedral* Cleavage. It may cleave in four directions so as to make an octahedron; as in fluorite.

(f) *Dodecahedral* Cleavage. It may cleave in six directions, having twelve faces and making a dodecahedron; as in sphalerite (an ore, the sulphide of zinc).

B. DEGREE. Cleavage may take place more or less easily. We call this differing in degree. We have

(a) *Perfect* Cleavage. See how easily mica, topaz, calcite separate.

(b) *Distinct* Cleavage. This is easy but not perfect. Feldspar has one direction perfect, a second direction distinct.

(c) *Imperfect* Cleavage. This is shown in apatite. It is quite readily obtained.

(d) *Indistinct* Cleavage; not easily obtained, as shown sometimes in hematite, copper pyrites, and cassiterite (tin ore).

Exercises with Crystals and Crystalline Forms.*

1: Cut four equal triangular pieces of cardboard, one inch on a side, and fasten these together so as to make a three-sided pyramid, using one piece as a base. You have the smallest number of faces that can be used in making a

* In experimental laboratory.

solid, and the simplest crystal form. If *tetra* means four, and *hedron* means base or side, is this a tetrahedron?

2. Make six square pieces of cardboard and combine them to form a cube. This is the next simplest form. What mineral have you that is of this shape?

3. Make six pieces of the shape of a rhombus, and combine these to form a rhombohedron. Your calc-spar specimen will be a model.

4. Make a tetrahedron of two inches on a side; mark the middle points on each side. Cut off each apex at the middle points marked, passing the knife at each section parallel to the opposite side. Place on four triangular pieces to cover the open spaces, and you have the octahedron, which illustrates cleavage of fluorite. Count the faces and say what *octa* means.

5. Cut twelve pieces, of the shape of the rhombus, one inch on a side. Combine these into a volume. How many faces has it? Define a dodecahedron.

Cut twelve pieces, each of which has five equal sides one inch in length. Combine these into a volume. If each face is a pentagon, what kind of a dodecahedron is it? What kind is the former one?

Have you a little steel wheel for cutting glass? Use glass instead of cardboard, holding edges together with thin, colored paper and a paste.

Wet a file with a mixture of turpentine and camphor gum, and bevel the edges of the glass by filing, if you care to do that.

Perhaps you can make these forms in wood or clay. They give ideas of forms assumed by mineral material in crystals and in cleavage. Why does each mineral have its own form of crystal and of cleavage? Do you suppose the shape of the molecule and the forces about it have something to do with this? Have you ever seen pieces of iron held end to end by a force? But you do not fancy, of course, that

what we ordinarily call magnetism arranges the molecules in a crystal.

6. Can you make a form with paper or otherwise to represent the regular quartz crystal? Examine such a crystal; what is the shape of the body of it? Of the two ends? Perhaps some of you can represent other crystals of your collection (by and by), of calcite, gypsum, halite, galena, fluorite, apatite, feldspar, magnetite, pyrite, diamond, etc., with paper, clay, or otherwise, to remain in the school collection.

7. Having your clay or card model of a cube, make a small hole at the centre of each opposite face. Run a thread or a fine rod of wire through from side to side, stopping at the exact surface. How many rods do we have? Are they of equal measure? If *isos* means equal, and *metron* measure, what does isometric mean? Shall we call these rods *axes*, and are they at right angles to one another? How then define the isometric system of crystals and of cleavage? Call two of these axes lateral, and one vertical; which shall we so name, and why?

Do you see that the surfaces are in a certain fixed position with reference to these axes, and that this determines their angles with regard to one another? Are these axes real or imaginary?

You can put axes in your glass models, puncturing the glass if necessary with steel point and turpentine as above.

You will notice that the three axes are not always of equal length in all your crystals, nor always at right angles. In one system it has three lateral axes. Your teacher will make other systems and names* if desirable.

8. Having a cube of clay, shave off symmetrically the eight triangular corners till you have the regular octahedron. Does this form then belong to the isometric system? Truncate or shave off the *edges* of the cube till you have the

* See author's *High School Manual*.

rhombic dodecahedron. To what system does the rhombic dodecahedron belong? If, then, while the molecules retain their symmetrical grouping about the axes, their shape allows other surface forms to appear on the crystal, how varied may the crystals be even in one system!

V. FRACTURE. Any mode of parting, not cleavage, is fracture, due to the irregular arrangement of the molecules. A mineral may have cleavage in one and fracture in another direction. Some minerals cleave so easily, it is difficult, or impossible, to get a fracture surface. Try calcite and galena.

1. *Conchoidal*. Examine a piece of flint. The fracture surface is rounded like a shell. *Conch*, means shell; *oid*, like. What shall we call this fracture?

2. *Even*. The surface is rough, but still quite even. See fracture of marble.

3. *Uneven*. Very irregular; see the fracture of topaz.

4. *Hackley*. Jagged, like broken iron. Break a piece of graphite.

5. *Splintery*; as in some minerals called *spars*. What does *spar* mean? Try also steatite.

VI. TENACITY (or Coherency). The meaning of this term as applied in mineralogy, is that strength of molecular attraction which resists pulling or forcing of the body entirely apart,—hardness, a phase of this property, given elsewhere, having reference to

the rigidity of molecules in their place tested conveniently on the surface.

The force that holds molecules or their aggregates together may be strong or weak, may seem to reach a long or short distance (so to speak), or to be evenly or unevenly distributed about the molecule.*

The following terms may be employed:

1. *Tough*. As corundum, pyrite, massive quartz. How difficult to break.
2. *Medium*. See gypsum, apatite.
3. *Weak*, sometimes expressed as frangible, fragile, etc. See halite, sulphur.

In weak we have the opposite of tough. Brittleness may or may not be associated with degrees of strength above; as quartz, tough when massive, brittle when crystal. Corundum is tough and pulverable, not brittle. Fossil gum and sulphur are weak and brittle. As compared with sulphur, graphite is weak and what?

4. *Malleable*. Can be hammered into thin sheets, as gold, copper. (See mallet.)

5. *Sectile*. Try a knife on gypsum, steatite. Can you cut or shave off a portion? Yes, but they *powder* under the hammer. Sectile means what?

* Our conception must depend upon what we imagine to be the ultimate condition of matter, and the cause or origin of cohesion. A more comprehensive mineralogical term for this property than "tenacity" would be "coherency" of the mineral. However the forces about the molecule act, strength or weakness goes with each manner of acting, causing the properties under tenacity to go in pairs or opposites. Where forces about the molecule are unequally distributed cleavage is favored.

6. *Pulverable*. Powders under hammer without flattening. See calcite, corundum, flint.

In 4, 5, 6 we have a gradation from malleable to non-malleable. In the malleable body the molecules move under the blow without letting go their hold on each other. They appear to roll about, the attractive force found equally on all sides of the molecular aggregates permitting this. In the pulverable body, the molecules let go instantly they are moved in the slightest by blow or otherwise. A pulverable mineral may or may not be brittle, weak, or hard. The malleable quality may be modified by heat, as in annealing, tempering. See iron manufactured to be brittle when cold, commercially called "cold-short." Note the hardness and weakness (brittle) of the slender round file.

7. *Flexible*. Bends, as scales of talc, hornblende.

8. *Elastic*. Bends and springs back again, as mica.

9. *Brittle*. Parts with or without bending perceptibly, as seen in glass, flint.

The elastic body allows molecules to move and draw back again to former position. The brittle body splits when once the fracture has started at a side or otherwise by a blow or by bending. Brittle bodies may be elastic, as in quartz ("marbles"); may be tough or weak. A fragile body is weak and brittle. Brittleness favors cleavage and conchoidal fracture.

10. *Hard*. Indented or scratched with difficulty.

11. *Soft*. Indented easily, but does not readily powder; as graphite.

12. *Friable*. Easily indented and easily powdered; as chalk.

Ice may be weak, brittle and soft; when very cold weak and brittle only. The pupil will determine the relation of *soft* to malleable and sectile on one hand and to tough and brittle on the other. Describe carefully in all the particulars of tenacity, corundum, diamond, massive and crystal quartz, copper, chalk, asphaltum, sulphur, graphite, ice.

VII. COLOR. What is meant by a beam of light? Have you learned that such a beam is composed of the "colors of the rainbow?" If a body is red, is it because all the colors of the light which falls upon it have been destroyed except the red, and the red is reflected? Why have minerals different colors?

While many names are given to colors, the following eight simple terms are used for minerals;—black, red, brown, yellow, green, blue, gray, white. For accurate description other words are added to these, as gold-yellow, milk-white. The pupil will find excellent practice in careful color description of minerals.

1. *Metallic Colors*,—those named from metals,—copper-red, silver-white, steel-gray, etc.

2. *Unmetallic Colors*,—ordinary colors and combinations, as snow-white, bluish-gray, greenish-black, bluish-black, blackish-blue, sky-blue, sea-green, pea-green.

You will see in diamond and precious opal what is called *play of colors*; in labradorite and in tiger-eye, what is called *change of colors*. Sometimes in Iceland spar and in quartz you see *iridescence*; in opal and in cats-eye, *opalescence*; in fluorite, *phosphorescence*, and on chalcopyrite and coal what is called *tarnish*.

VIII. STREAK. This term is used to mean the color of the powder of a mineral. The external surface, more especially of silicates, may have a different color from the powder which is the true color. Obtain streak by drawing the mineral across a piece of rough porcelain, or by powdering a fragment.

IX. LUSTRE. This property, like that of color, is due to the action of the surface molecules upon the waves of ether which we call light.*

A. The kinds of lustre are:

1. *Metallic*. This is a lustre like that of metals,—see pyrite, galena, etc. Have they not a metallic look? A less degree is *sub-metallic*.

2. *Vitreous*,—like *broken* glass. See broken quartz. This is the lustre of a large number of minerals. *Sub-vitreous* is a less degree, as in calcite.

3. *Adamantine*, like diamond and corundum gems. Also sphalerite crystals. Adamantine resembles resinous lustre; resinous resembles greasy. See the gradation in the diamond gem adamantine, carbonado resinous, and bort greasy lustre.

4. *Resinous*, like yellow resins,—as opal, sphalerite, sulphur.

5. *Greasy*,—like “greasy” quartz, serpentine.

*When some of the light is reflected quite at the surface layer of molecules of a mineral, and some after penetrating to a slight depth is then reflected, the latter will be less brilliant than the former. The blending in the eye of reflected rays of different brilliancy produces in the eye the effect of lustre.

6. *Pearly*,—like steatite, selenite, cleavage face of feldspar.

7. *Silky*,—like fibrous gypsum (satin spar).

8. *Dull*,—total absence of lustre, as chalk.

B. There are several degrees of lustre:

1. *Splendent*. You may be able to see images on the surface, as in some quartz and hematite crystals.

2. *Shining*. It may shine strongly but not show well-defined images, as calcite, celestite.

3. *Glistening*,—reflecting, but no images,—as talc, chalcopyrite.

4. *Glimmering*, imperfect reflection, as flint, chalcedony.

X. DIAPHANEITY, or Transparency. The molecules of a body may be so harmoniously placed with reference to the waves of light that these may pass right through without being destroyed. Or they may be partly or wholly stopped.

If in passing through, all but the blue light waves are stopped and the latter are allowed to pass, what will be the color of the transmitted light? Would it be right to say the transparent mineral colors the light? Your minerals may be as follows:

1. *Transparent*. Do objects show quite clearly through the mineral? Try the quartz crystals; the Iceland spar. *Semi-transparent* is like cairngorm, called also smoky quartz.

2. *Translucent*. Does the light shine through,

but not so as to show objects? That is like chalcedony, and some very light-colored flint. *Sub-translucent*, most kinds of flint.

3. *Opaque*. Does light come through coal at all?

If you have ever looked through a glass prism, you have noticed how objects seem moved out of their proper places. This is because the light itself is bent out of its course in passing through the prism, and we call this effect, *refraction*. Sometimes when a beam of light is allowed to pass through a mineral, it is bent and twisted in such a way that it comes out in two beams instead of one. We can easily believe it is the arrangement of the molecules that causes this result. We call it *double refraction*.

When the beam in passing comes out still as one beam, we call the mineral,

4. *Singly refractive*, as in diamond. Glass also is singly refractive. How then can you tell a paste (glass) imitation from a true diamond?

When the light is separated into two beams we call the mineral,

5. *Doubly refractive*; as in calcite, quartz, ruby, sapphire, etc.

6. **PLEOCHROISM**—dichroic, triochroic. Zircon, diaspore, ruby, sapphire. When in double refraction the emergent beams are of different colors the mineral exhibits pleochroism, which may be dichroic or trichroic. In doubly refractive minerals light passing along the vertical axis has only single refraction. This direction is called the optical axis, and the crystal is uniaxial. The triochroic or three-color

crystals have two optical axes and are biaxial. The differences of molecular arrangement which cause single and double refraction and pleochroism are closely connected with the systematic classification in the six systems of crystals.

Make a pin-hole in a cardboard. Place your transparent clac-spar, which we call also Iceland spar, over this. You see two holes instead of one. You do not now need to be told why. Beside by hardness, now would you know a ruby from a red glass, and a sapphire from a blue glass imitation? How know a diamond from a sapphire of about the same look?

XI. TOUCH. Minerals, like steatite, may feel greasy or oily to the hand. We call this *unctuous*. Others we may describe as *smooth* and *harsh*.

XII. MAGNETISM. Some minerals have so much iron in them that they attract, or are attracted by, a magnet. When this force seems very weak, suspend the magnet by a thread near the mineral. Sometimes the magnet will only pick up the powder of the mineral. Sometimes the iron-ore must be strongly heated before the magnet acts.

XIII. ELECTRICITY. Some minerals become electric by rubbing with woolen cloth. They will then attract bits of paper. Some are electric after being suddenly heated or cooled,—pyro-electric.

XIV. WEIGHT. You noticed quickly at the beginning how your minerals differ in weight. Shall we imagine that in some the molecules are nearer together than in others? We designate the property

of weight in minerals by specific gravity. They are all compared with the weight of water.

If a cubic inch of water weighs a certain amount, and a cubic inch of quartz weighs two and six-tenths times as much, we say the specific gravity of quartz is 2.6.

The pupils will learn specific gravity of minerals in the experimental laboratory.

Note on specific gravity,—a standard of weight.

Call ordinary quartz, Spec. Grav., 2.6.....medium.

Much less than quartz call.....light.

Much greater, call.....heavy.

II. THE CHEMICAL TESTS.

In what has preceded, we have had physical tests. They *do not change* the nature of the mineral. Besides these there are chemical tests. They, as you will see, change the portion of mineral examined. In chemical tests, we take the mineral apart and find what is in it. Thus we may find gypsum is composed of lime (calcium), and sulphuric acid (sulphate), and water (hydrous). See the formula $\text{Ca SO}_4 + 2\text{H}_2\text{O}$ and chemical name. Some of the chemical tests point out important processes in the useful arts. In our school work, we may use the following:

15. The closed tube. 16. The open tube. 17. Solution in acids. 18. The blowpipe flame with mineral in forceps. 19. The blowpipe flame with mineral on charcoal. You will learn what these are by seeing the apparatus, and using them before the class. Your teacher will select such chemical tests as directly apply in each case. For instance, he will show you

how to make plaster of Paris; how to get metallic lead from galena, etc.

Having heated a bit of powdered mineral (gypsum) in a test tube, moisture deposited on the walls indicates what?

A mirror-like deposit on the walls of the open tube may indicate mercury. See if there are any odors with this tube.

Putting a drop of acid (hydrochloric) on a mineral, if it bubbles up (effervesces) without any odor, the mineral is likely to be a carbonate. What gas comes off?

If it has a certain very disagreeable smell, the mineral is a sulphide. The gas that comes off is hydrogen sulphide, H_2S

Having a fine splinter of the mineral, hold it with the forceps in the blowpipe flame and note whether it melts easily, with difficulty, or not at all. Does it color the flame? Does it give a smell of burning sulphur (sulphide)?

Having a little of the powdered mineral in a small cavity in charcoal, and driving the flame of the blowpipe upon it, does it fuse? change color? give an odor? Is a malleable globule formed which will mark upon paper? If so, what is it? Is a red malleable globule formed? What is it? A white globule may be silver. A magnetic mass would be what?

A yellow coating around the powder on the charcoal would be lead, a white coating, zinc.

A COLLECTION OF ROCKS

FOR PUPIL'S STUDY.

These will be:

GRANITES, several kinds;

GNEISS, MICA SCHIST, SLATES;

IGNEOUS ROCKS, trap, etc.;

SANDSTONES, several kinds;

LIMESTONES, marbles, etc.;

CONGLOMERATES, SHALES.

Find material where the rock crops out in your vicinity or at stone yards. Obtain from the workmen at stone yard the special name of the granite or other rock, and the locality whence it came. Trim specimen to be oblong, flat, thin. Cabinet specimen, four inches long. Pupil's specimen, smaller.

Analysis of Rocks.

I. GRANITES. Examine a piece of freshly broken, coarse granite. Do you see parts that are glassy in their look with irregular fracture, very hard? Can this not be quartz?

Do you see other portions, colored or white, not so hard, and with smooth cleavage faces? Is that not the feldspar?

Can you not lift up with point of knife thin elastic scales of mica? Of what then is granite composed?

Sometimes these elements are quite fine and a microscope may be used.

Here is one with fine black scales, of hornblende. They are not elastic, hence not mica. Call this syenite.

Granite rock is not divided into layers.

2. GNEISS is like the granite, except that it may be found in thick layers, which lie straight or curved.

3. MICA SHIST splits into thin layers, with abundance of mica.

4. The SLATES are hard, compact, fine-grained rocks, not at all like the granites, that separate easily into thin leaves crosswise to the layers of rock.

The above are called metamorphic rocks, having been changed from sedimentary rocks and recrystallized by action of heat and hot water. When molten rock-material has flowed out from the earth, it forms on cooling what we call

5. IGNEOUS ROCKS. These are dark rocks shown by the microscope to be finely compact and crystallized, composed mostly of a kind of feldspar. They are such as trap, basalt, obsidian, lava, pumice stone, etc. Granite is also formed as an igneous rock. The cores of extinct volcanoes are granite. But the granite has cooled very slowly and formed large crystals.

6. SANDSTONE. Is your rock composed of grains of sand, more or less firmly held together? Examine the grains with a microscope and see how *worn* they are, just like sand.

7. LIMESTONE. Is the rock easily scratched, and does it effervesce when an acid is put upon it? This is limestone. Does the limestone seem to be finely crystallized? This is marble.

8. CONGLOMERATES. Does your rock contain pebbles and other fragments? Call it pudding stone, or conglomerate.*

The last three above are sedimentary. In studying a rock follow the mineral scheme as far as it applies. State uses of rock and where found in use. Observe that a *mineral* in large masses may be a rock. Sand and pebbles may be quartz.

* This rock may be sign of glacial action.

Student's Collection of Metals and Alloys.

Copper, brass, bronze, tin, lead, zinc, iron, steel, aluminum, German silver, pewter, quicksilver, gold, silver, platinum.

Size of specimen of the ordinary metals one and one-fourth inch square. Devise a scheme for description of metals.

Supplementary Minerals.

Asphaltum, fossil gum, sulphur, cinnabar, serpentine, sphalerite, arsenopyrite, cassiterite, varieties of quartz, such as sand, onyx and other agates, crystals, etc.

Treat these as you have the other minerals.

PART II.

EDUCATIONAL, PHYSIOGRAPHIC AND ECONOMIC MINERALOGY.

A PRIMER COLLECTION OF MINERALS.

Grouped According to the Scale of Hardness.

NOTE.—The symbols and chemical names are given for convenience of those who wish to complete the labelling of their specimens. For experimentation, physiographic relations and uses, see succeeding analyses.

I. STEATITE. ($\text{H}_2\text{O}.3\text{MgO}.4\text{SiO}_2$. Ternary; hydrous silicate of magnesium.) Steatite has peculiar physical properties; chiefly valuable like graphite because of the inertness of its chemical properties.

GRAPHITE. (C. Carbon; a native element, non-metal.) Graphite has remarkable physical properties and uses.

II. GYPSUM. ($\text{CaSO}_4.2\text{H}_2\text{O}$. Hydrous calcium sulphate.) A typical hydrous mineral and sulphate; common ingredient of earths and rocks. Instructive physiographic lessons.

SULPHUR. (S. Sulphur; native element, non-metal.) An acidic component in minerals; active agency in mineral and rock changes.

HALITE. (NaCl . Sodium chloride. Binary.) Interesting physical properties and physiographical relations.

MICA. (Muscovite, $2\text{H}_2\text{O}.\text{K}_2\text{O}.3\text{Al}_2\text{O}_3.6\text{SiO}_2$. Hydrous silicate of potassium and aluminum. Ternary. Hydrous unisilicate.) A well known component of rocks.

III. CALCITE. (CaCO_3 . Anhydrous calcium carbonate.) Typical carbonate, common in rocks; remarkable physical properties; instructive chemical lessons; interesting round of physiographic relation. (With this compare iron carbonate, FeCO_3 .)

COAL. (Carbon, hydrogen and a little oxygen; mixture of hydrocarbons.) An oxygenated hydrocarbon, instructive in its physiographic relations and uses.

CRYOLITE. ($3\text{NaF}.\text{AlF}_3$. Fluoride of sodium and aluminum.) Binary, fluoride; ore of aluminum.

GALENA. (PbS . Lead sulphide.) A typical sulphide; interesting physical properties and physiographic association; ore of lead.

IV. FLUORITE. (CaF_2 . Calcium fluoride.) Remarkable physical properties.

AZURITE. ($2\text{CuCO}_3.\text{Cu}(\text{OH})_2$. Hydrous carbonate of copper.) Ore of copper.

MALACHITE. $\text{CuCO}_3.\text{Cu}(\text{OH})_2$.

SPHALERITE. (ZnS . Zinc sulphide.) Associated physiographically with lead. Ore of zinc.

V. APATITE. ($3\text{Ca}_3(\text{PO}_4)_2.\text{CaF}$. Calcium phosphate.) Ore of phosphorus.

HEMATITE. (Fe_2O_3 . Ferric oxide.) Ore of iron.

A typical metallic oxide; instructive physiographical relations. Limonite, the hydrous oxide, may be considered with this ore,— $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$.

VI. FELDSPAR. (Orthoclase, $\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$. Silicate of aluminum and potash.) Ternary, anhydrous unisilicate. A typical silicate and rock builder; instructive physical properties and physiographic relations.

MAGNETITE. (Fe_3O_4 , Black oxide of iron.) Ore of iron; instructive in its origin.

PYRITE (FeS_2 , Iron disulphide.) Active agency in physiographic changes of rocks.

VII. QUARTZ. (SiO_2 , Silicon dioxide.) Acidic oxide, a great mineralizer, acidic component of minerals—the silicates—and rocks.

VIII. TOPAZ. (AlF_2SiO_4 (Brush). Aluminum silicate, mostly.) Anhydrous subsilicate. Scale of hardness; gems.

IX. CORUNDUM. (Al_2O_3 , Aluminic oxide.) Valuable gems of wonderful physical properties; inert metallic oxide; a typical abrasive. Basic component of many minerals and rocks.

X. DIAMOND. (C. Carbon. Native element.) Allotropic carbon, in some respects the antithesis of graphite and other carbon.

(Hornblende. Silicate of aluminum, magnesium and calcium, with some iron, potassium and sodium. Formula very complex. Anhydrous bisilicate; component of rocks.)

A MODEL FOR GUIDANCE OF PUPIL.

With pen according to scheme on page 81.

STEATITE, TALC.*

HARDNESS,—The hardness of steatite is No. 1.

FORM.—Its form is massive and its

STRUCTURE,—structure is crystalline to amorphous. Foliated talc is crystalline; soapstone ^{amorphous} amorphous.

CLEAVAGE,—The cleavage is basal; perfect in foliated talc; imperfect to wanting, otherwise

FRACTURE.—Its fracture is uneven, splintery,

TENACITY,—and its tenacity is sectile, flexible, weak, soft.

COLOR,—The color of the mineral, green, greenish gray,

STREAK,—the streak white or light.

LUSTRE,—The lustre is pearly, glistening, and

DIAPHANEITY,—the diaphaneity translucent to opaque. Foliated talc is nearly transparent.

TOUCH.—The touch of steatite is unctuous.

MAGNET.—It is not affected by the magnet,

ELECTRICITY,—but is sometimes electric by friction.

WEIGHT.—The mineral is of medium weight,

SPECIFIC GRAV.—having specif gravity of 2.7.

*From Cherokee Co. North Carolina.

CHEMICAL PROPERTIES.— In closed tube, open tube, and in acids, there is no effect. B.P. strongly heated the mineral fuses on a thin edge. But in c.t. when red hot it gives off a little moisture.

COMPOSITION,—hydrous silicate of magnesium.

FORMULA,— $H_2O. 3MgO. 4SiO_2$.

CLASSIFICATION,—a ternary comp.; hydrous silicate.

CHARACTERISTIC TESTS,—softness, color, touch.

VARIETIES,—foliated talc, steatite, soapstone, and pseudomorphous forms. The general name is Talc.

USES,—Used for fire pots, as lubricator, polisher, medicine in talcum powders; slate pencils, French chalk; culinary utensils, sinks, registers, ornaments, etc. Used as taken from the mine.

NATURAL HISTORY,—Found in beds, chiefly in metamorphic rocks; also pseudomorphous by alteration of other rocks.

HISTORY,—Theophrastus, (died 288 B.C.) called it magnetis. From this we have magnesium. Pliny, the naturalist (died 79 A.D. at Pompeii) in his Natural History calls the mineral steatilis, from a word meaning fat. Talc is German, middle ages. Talcum, Lat. & Latin. Arabs called it Salk.

ANALYSES OF THE PRIMER COLLECTION.

Method.

The "Carbon Group" is introduced with lessons on forms of carbon seen in charcoal, lampblack, wood, etc.; the nature of carbon dioxide, how formed, lime-water as a test; and oxygen. Other supplementary science is given as the minerals suggest.

The pupils having specimen in hand, *by their own study* of the mineral following this manual pages 15 to 31, fill outline blanks as shown by models pages 39 and 40, employing the following notes, pages 43 to 76, *only to supply what they cannot otherwise readily determine.*

They will, when desired, consult dictionaries (Century), encyclopædias (Britannica), Tarr's Economic Geology of the United States, Tarr's and Davis's Physical Geographies, and Geology (Scott). For standard mineralogy refer to the works of Dana and Brush.

Later in the course, in advanced physics, the optical effects of minerals in double refraction, polarization and pleochroism with reference to molecular structure of crystals are further studied. In third

year, with general chemistry, determinative mineralogy is completed as indicated quite fully in the following notes, and the economic processes by which utilities are derived from the minerals are more fully dwelt upon in connection with Newell's chemistry.

In senior year, in qualitative analysis, the minerals are analyzed by the wet process, and elements accidentally present are found and the work recorded in special blankbook.

The metal working departments of the school extend the study of properties and workings of minerals.

[NOTES.—PHYSICAL, CHEMICAL, PHYSIOGRAPHIC, arranged according to a Teachers' Progressive Course page 11.]

GRAPHITE, Plumbago, Black Lead.

(Ceylon, Asia.)

FORM.—Rarely found in tabular crystals of the hexagonal system.

Conductor of electricity.

SPEC. GRAVITY.—2.1.

CHEMICAL PROPERTIES.—In c. t., o. t., acids, B. B. without effect; but graphite heated with KClO_3 , or with KNO_3 (saltpetre), burns, forming CO_2 , proving graphite to be carbon.

[NOTE.—c. t.=closed tube; o. t.=open tube; B. B.=before the blowpipe. Burn graphite in deflagrating spoon in small bottle of air over limewater; observe whitening of limewater. Also heat splinter of graphite B. B. *white hot* without effect (owing to refractory nature of graphite). Science in the grades—shows composition, and useful properties of the mineral.]

CHARACTERISTIC TESTS.—Color, touch, streak, degree of hardness; carbon dioxide with limewater..

VARIETIES.—Amorphous; foliated (crystalline, Ceylon); scaly (crystallized, Ticonderoga, N. Y.)

USES.—Mingled with fine clay it is employed in making leadpencils, crucibles; as stove polish; lubricator; conductor of electricity in electroplating.

Used as taken from the mine; must be pure.

NATURAL HISTORY.—Found in the oldest or metamorphic rocks; sometimes in metamorphic coal beds; also it is the product of furnaces; and is found at the tips of used electric carbons; found in meteoric iron and in cast iron.

HISTORY.—Wrongly called black lead and plumbago, there being no lead in it.

Werner named it graphite from *graphein*, to write.

NOTE.—Carbon in the allotropic state of graphite, has at least three graphitic allotropic forms—that seen in natural graphite, that found at tips of electric pencils and that found in carbides of iron. In connection with this, consider that ordinary carbon has several allotropic forms—charcoal, lampblack, etc., and diamond has three markedly different forms. How varied are the states which this single element may assume, widely diverse in physical properties, and all due probably to differences in molecular grouping.

CALCITE.

FORM.—Limestone, chalk, stalactite, tufa, marble are ———; calc-spar, dog-tooth spar, ———. The crystal forms are of the hexagonal system, rhombohedral division.

STRUCTURE.—Of calc-spar and crystals, ———; marble, ———; limestone, chalk, stalactite, are ———.

FRACTURE.—In calc-spar, wanting.

DIAPHANEITY.—Transparent to opaque; strongly doubly-refractive (in Iceland spar); in crystals, sometimes highly iridescent.

ELECTRICITY.—Calc-spar electric by friction.

WEIGHT.—Medium; spec. Gr.—2.7.

CHEMICAL PROPERTIES.—In closed tube, powdered and strongly heated, gives no moisture, hence is anhydrous; but, carefully tested in tube with drop of limewater on end of glass rod, shows CO_2 has been driven off,—illustrates making of quick lime. In o. t., no different effect. With HCl acid, effervesces, CO_2 gas given off. B. B. infusible, glows brightly; colors flame reddish yellow,—sign of calcium. When cool, placed on pink litmus paper and touched with drop of water, suddenly forms slaked lime, Ca(OH)_2 , with slight steam. CaO (quicklime) + H_2O = Ca(OH)_2 , while the pink litmus turns blue. The last is called “the alkaline reaction.”

Dissolve the Ca(OH)_2 in water,—this gives the “lime water.” Pass CO_2 through clear lime water, a white precipitate appears; that is, CaCO_3 *reappears*. Pass excess of CO_2 through the precipitate,—the CaCO_3 redissolves. This shows action of CO_2 in nature, dissolving limestones, by the aid of water, to form caves, and redepositing to form stalactites or to bind rocky fragments; also similarly it dissolves and redeposits iron carbonates, and other carbonates.

CHARACTERISTIC TESTS.—The cleavage, hardness, effervescence; the quick-lime test B. B.

VARIETIES.—Limestone, chalk, marble, tufa, stalac-

tite, Mexican onyx, calc-spar, Iceland spar, dog-tooth spar, oriental alabaster (see Gypsum).

USES.—Lime; mortar; building stone; ornamental stone; mantels; flux; glass making; CO_2 ; scientific instruments. Quick-lime is obtained by roasting in kilns. Used as mined or quarried,—finer grades (marbles) are polished.

NATURAL HISTORY.—Calcite, in immense strata, is found in all geological periods as limestone and marble; in fissures and veins it is found as crystals and calc-spar; in caves as stalactite. Physiographically, most limestone beds indicate a former sea bottom of rather shallow depth of clear, warm and gently moving waters; and are the remains of ancient marine life, such as brachiopods and other bivalves, corals, polyps, crinoids, etc. Chalk beds compacted of myriads of microscopic calcareous skeletons may form in deep or shallow water. The crystallized structure of marble indicates upturnings of strata and metamorphism of the limestone by heat under pressure.

Bearing these considerations in mind, we are able to reconstruct in imagination the geographical outlines of the earth at various past times when the life of that period existed. Thus, the widely extended Trenton limestone indicates that in Silurian times nearly the whole of North America was under oceanic waters. The limestone beds are also often the repositories of vast mineral segregations, as lead, zinc, silver and other sulphides in the limestones of Missouri,

Nevada, and other western regions; the zinc mines of New Jersey and the hematite beds of the Appalachians.

Note the round of CaCO_3 , dissolved from the soil, transported by rivers to the ocean, secreted by animal life, reconverted to limestone beds, etc.

Calcite is from the Latin *calx*, meaning burnt lime; Latin for marble is *marmor*. *Spar*—calc-spar—means a chip or fragment, frequently used in mineralogy.

COAL.

HARDNESS.—.5—2.5.

Compressed by nature in layers, it sometimes simulates crystalline structure and cleavage.

TENACITY.—In cannel and jet sectile.

SPECIFIC GRAVITY.—From 1 to 1.8, the heaviest being anthracite.

CHEMICAL PROPERTIES.—Strongly heated in c. t., or in clay pipe covered with clay, gives off moisture, gases, sulphur fumes and tarry products. Coke is left in retort. [Illustrates gas and coke making; heat must be strong or coal very soft.] In o. t. burns. Coal is unaffected by acids. B. B., takes fire, burns without melting. [Some soft coals soften or “cake” in the furnace.]

COMPOSITION.—Beside carbon and hydrogen, there is a little oxygen. Coals are a mixture of oxygenated hydrocarbons.

FORMULA.—Evidently cannot be definitely written.

CLASSIFICATION.—Oxygenated hydrocarbons.

CHARACTERISTIC TESTS.—Color, hardness, combustibility without melting. [Distinguished from asphaltum which melts.]

VARIETIES.—Anthracite, bituminous, cannel, jet, lignite, peat. Anthracite is sometimes called stone coal; bituminous may be brown.

USES.—Fuel, source of gas, tars, etc.; various dyes, pigments; reducing agent in metallurgy and other processes. Coal is used as mined; useful products obtained by distillation by processes too numerous to be here described. [See encyclopædias and chemistries.]

NATURAL HISTORY.—Produced by slow distillation of vegetation in swampy regions that have been buried by some process in nature. Physiographically the coal beds represent extensive swampy regions that have been successively elevated and depressed, known as the Carboniferous Age of the Palæozoic Era. There have been, however, several minor coal eras. The elevation, with vegetation, continued many thousand years; succeeded by subsidence and submersion much longer and many times repeated,—so that sedimentary rocks, including even limestones, intervene between coal strata.

The interior of South America along the broad, oceanic Amazon is one vast jungle region, and ex-

tensive swamp areas are found to east of the Andes. The conditions would need to change but slightly to convert the interior of South America into a coal formative period. So we may imagine the interior of North America in ancient times a vast jungle and swampy region west of the Blue Ridge and along the oceanic Ohio and Mississippi rivers and tributaries of that day.

The word coal (originally *cole*), is Anglo-Saxon, and meant what we now call charcoal. The mineral coal was called stone coal. The word anthracite is from Greek *anthrax*, meaning coal, and an *anthrakeus* was a charcoal maker. He drove quite a business. Aristotle mentions "certain stones which burn." Theophrastus, successor to Aristotle as a great science teacher, speaks of stones which will "kindle and burn like charcoal." Red glowing gems,—garnets, carbuncles,—were called *anthrax*.

The use and consumption of mineral coal is of very recent date, depending apparently upon a suitable means of burning.

Cannel is a candle, referring to use cut in sticks. Jet, harder than cannel, is set in jewelry.

SULPHUR.

FORM.—————; also ————, orthorhombic system, and monoclinic system, (dimorphic).

Translucent, transparent, doubly refractive.

Highly electric by friction.

SPEC. GRAV.—2.

CHEMICAL PROPERTIES.—In c. t. melts at low heat; at higher heat becomes thick and black; at boiling becomes fluid again; sublimes. In o. t. burns; ordinarily insoluble; B. B. melts, burns.

CHARACTERISTIC TESTS.—Color, fusibility, burning.

VARIETIES.—Massive; (roll sulphur, or brimstone, flowers of sulphur, lac sulphur); crystal.

USES.—Employed in making gunpowder, vulcanizing rubber, in cements, in making sulphuric acid and other chemicals; used in medicine. Used as found though sometimes distilled.

NATURAL HISTORY.—Found near volcanoes, active and extinct, and associated with beds of gypsum. Sulphur is constantly forming about active volcanoes by the mingling and chemical action of two gases,—sulphur dioxide, SO_2 , and hydrogen sulphide, H_2S . $\text{SO}_2 + 2\text{H}_2\text{S} = 2\text{H}_2\text{O} + 3\text{S}$. The H_2O falls as rain, while the S accumulates on crags and mountain side.

Sulphur is a great mineralizer and is found with many ores as sulphides and with minerals as sulphates.

The Latin is *sulfur*.

GYPSUM.

FORM.—Ordinary, alabaster, foliated selenite are ———; selenite crystals are of the monoclinic system.

CLEAVAGE.—Selenite in basal direction, perfect; in other directions, difficult.

SPEC. GRAV.—2.3

CHEMICAL PROPERTIES.—Heated in c. t. much moisture is driven off; plaster of Paris is left in the tube. In o. t. the same. The mineral is slightly soluble in water. (Powder a fragment, boil in test-tube with water, filter, evaporate the clear liquid, note the residue); more soluble in HCl acid.

B. B. fuses, whitens, turns flame reddish yellow, (calcium), gives alkaline reaction on pink litmus paper. (A fragment strongly heated in reducing flame B. B. and placed on clean silver blackens it on moistening,—a sign the mineral is a sulphate.)

CHARACTERISTIC TESTS.—Hardness (softness), moisture in c. t., and plaster of Paris residue.

VARIETIES.—Ordinary or rock gypsum; alabaster,—snowy and Devonshire spar; selenite; fibrous—i. e., satin spar and plumose gypsum.

USES.—Plaster of Paris, made by heating in ovens; kalsomine; somewhat as fertilizer; vases and other ornamental purposes.

NATURAL HISTORY.—Found in extensive beds evidently formed by deposit from quiet waters holding gypsum in solution. A bed of gypsum is a sign of an ancient interior drainage area of the Earth's surface, just as to-day lakes having no outlet deposit gypsum. The mineral also is formed about volcanoes by action of sulphur compounds on limestone, and about sulphur springs. Gypsum from the rocks and soil, per-

haps forming constantly by action of pyrites and other sulphur compounds on limestone, washed by the rains, carried by the rivers, accumulates in the lakes. Physiographically a bed of gypsum indicates features regarding the drainage at some past period, and is generally overlaid with a bed of salt similarly formed.

Gypsos, ancient Greek, meant burnt earth. *Selene* means the moon, referring to the pearly lustre of selenite. *Alabastritis* (Theophrastus), from which *alabastra* (vases) were made was probably a variegated calcite of stalactitic origin, called to-day oriental alabaster; but with us the term alabaster refers as here to a variety of gypsum.

PYRITE.

FORM.—Massive; also crystal, isometric system, commonly cubic.

STREAK.—Brownish, dark with greenish tinge; (quite green it indicates chalcopyrite, copper).

SPEC. GRAVITY.—5.

CHEMICAL PROPERTIES.—Heated in c. t. it decrepitates; sublimate of sulphur forms on cold walls of the tube; becomes magnetic; in o. t. it burns with fumes of sulphur dioxide, SO_2 . (The first illustrates the preparation of sulphur by distillation from pyrite; the second the manufacture of sulphuric acid or other sulphur reagent.) Dissolves in nitric acid. B. B. the sulphur burns away leaving residue attracted by the magnet.

CHARACTERISTIC TESTS.—Hardness, color, streak, strikes fire from steel; B. B. tests.

VARIETIES.—Ordinary, pyrrhotite (slightly magnetic), marcasite, auriferous (or gold-bearing); if much gold is present, it is gold ore; if much copper, it is copper pyrites or chalcopyrite; if arsenic, it is arsenical pyrite or mispickel. Any iron pyrite may be called "fool's gold" but may actually contain gold.

USES.—For ornaments; source of sulphur; source of SO_2 for sulphuric acid; somewhat as source of iron and iron compounds, but sulphur is difficultly removed.

NATURAL HISTORY.—Pyrite is found widely disseminated, sometimes in huge crystals, sometimes in extensive ledges. Hundreds of thousands of tons are mined annually, sources of sulphur and sulphuric acid. It is generally associated with copper, gold and other metals. It is an unstable mineral, and, breaking up into oxides of iron and sulphuric acid, is a great disintegrator of rocks, and former of new minerals. No stone containing pyrite is suitable for architectural purposes.

Pyrite is from *pur*, meaning fire, and means fire-stone.

GALENA.

FORM.—Massive; also crystal, isometric system, cubic habit.

SPEC. GRAV.—7.5.

CHEMICAL PROPERTIES.—In c. t., decrepitates, fuses, yields vapors of sulphur, sublimes and coats the tube black and yellow (S): in o. t., burns somewhat with coatings and vapors. With HCl acid, gives smell of hydrogen sulphide; with nitric acid, dissolves leaving a globule of sulphur, and lead sulphate by oxidation of PbS. B. B., on charcoal, fuses, burns away the sulphur, and deposits a light brown coating of litharge, PbO. A globule of melted lead is left on charcoal, which remains liquid quite long on account of low fusing point of lead, and when cold may be cut with knife or will mark paper.

CHARACTERISTIC TESTS.—Weight, hardness, color and lustre; blowpipe; structure.

VARIETIES.—Ordinary, argentiferous.

USES.—Ore of lead; metal extracted by roasting process and closed retort combined.

NATURAL HISTORY.—Found everywhere and in rocks of all ages, metamorphic as well as stratified; found in great masses called "segregations," in limestone, associated with silver, iron, copper, zinc, quartz. Many noted silver mines are only argentiferous galena. This last mentioned has crystallized structure, fine or coarse.

The Greek word *galene* means "calmness" or "stillness of the sea." Said to have been recommended by Galen as an antidote for poison.

HALITE.

FORM.—Sometimes massive; often in cubic crystals of the isometric system.

SPEC. GRAV.—2.1.

CHEMICAL PROPERTIES.—In closed tube, decrepitate, melts; in o. t., the same. Soluble in water, saline taste. B. B., fuses, colors the flame bright yellow, sign of sodium. With H_2SO_4 , gives HCl acid.

CHARACTERISTIC TESTS.—Hardness, form, taste.

VARIETIES.—Halite.

USES.—Food; preservative; source of sodium and sodium compounds; of chlorine and chlorine compounds (formerly employed as money among eastern peoples).

NATURAL HISTORY.—Found in sea water, in mines as rock salt, and as brine in the rocks. Estimated that if the salt of the ocean were extracted it would equal 14 continents of size of Europe above ocean level. Physiographically, beds of salt indicate ancient salt marshes, lagoons of the ocean and also extensive interior drainage regions. Observe the great interior drainage area of Eurasia, 4,000 miles long, receiving immense rivers into interior salt oceans.

The salt deposits in Onondaga and Wyoming Counties, N. Y., and across Lake Ontario in Canada indicate that in Silurian times there was an extensive interior drainage area in this part of North America, though Lake Ontario is now fresh, having an outlet.

Lake Huron is bordered by salt beds of Carboniferous age. The various salt deposits of the Earth are interesting features in reconstructing the geography of their day. The words "salt have lost his savour" have reference to salt used in barter (money) that has been adulterated with white earth. [See Encyc. Brit.]

The Greek word *hals* and Latin *sals* mean sea or salt,—whence halite.

HEMATITE.

FORM.—Massive, botryoidal, kidney shaped; also crystal, hexagonal system, rhombohedral.

STRUCTURE.—Amorphous; fibrous, lamellar, scaly; also crystallized.

TOUCH.—Harsh; ochres are unctuous.

MAGNET.—Hematite sometimes in fine powder is picked up by magnet.

SPEC. GRAV.—5.

CHEMICAL PROPERTIES.—In c. t., pure hematite gives no moisture; becomes magnetic. Most massive hematite gives a little moisture; if much moisture it must be called limonite. In o. t., the same. Dissolves in HCl acid. B. B., infusible; becomes magnetic.

CHARACTERISTIC TESTS.—Weight, hardness, streak, blowpipe.

VARIETIES.—Specular; micaceous or scaly; fibrous including "red" hematite and kidney; argillaceous,

from argilla, clay, the most abundant ore. Ochreous, a red pulverulent ore (yellow ochre is limonite).

USES.—Ore of iron; ochre employed as paint; fine specular polished for jewelry. Metal extracted by carbon in blast furnace.

NATURAL HISTORY.—Found extensively in beds of all ages, metamorphic as well as sedimentary. Mined largely in N. Y., Penn., Ala., Mich.; immense beds in the Rocky Mountains. The most abundant ore of iron produced in the U. S.

Physiographically, iron is a mineralizer as well as rock builder, a cement for detritus especially of sand; gives color to clay and stone; its oxides and carbonates are associated with the action of water and sedimentation in swamps (and hence likely to be contiguous to coal); dissolved by percolating waters (more freely if the water has CO_2 in it), the iron oxides and carbonates are transported among the rocks to fill cavities or to actually replace other rock material,—as where ore replaces limestone, or flint, or even fossils that have been dissolved away. Replacement through agency of water seems a sufficient agency in accounting for these extensive and useful mineral formations. With hematite, study magnetite, limonite and siderite, noting how the ore changes from one form to the other, and especially the co-operation of CO_2 .

The Greek word *haima* means blood, and the haimatite of Theophrastus was bloodstone.

MAGNETITE.

FORM.—Massive; isometric system, octahedral.

Strongly attracted by magnet.

SPEC. GRAV.—5.1.

CHEMICAL PROPERTIES. In c. t., o. t., without effect; dissolves in HCl acid. B. B. infusible.

CHARACTERISTIC TESTS.—Form, color, streak, magnet.

VARIETIES.—Ordinary; lodestone.

USE.—Ore of iron; extracted by blast furnace.

NATURAL HISTORY.—Found in eruptive rocks in crystal grains; found in immense lens-shaped segregated masses in oldest or metamorphic rocks. Magnetite has the largest percentage of iron (.72) of the ores. Beds of magnetite may be discovered by aid of a magnet above the surface. Beds lying in direction of meridian, by the inductive influence of the Earth's magnetism may become magnetized. Such magnetite is called load—or lodestone.

Ancient Greek name *magnes*; same origin as *magnetis*, though the latter referred to soapstone.

QUARTZ.

The crystal is hexagonal.

STRUCTURE.—Amorphous; crystalline in the crystal forms. [Though the crystals lack the cleavage that ordinarily accompanies crystalline structure, because the crystals are doubly refractive, and behave like uniaxial structure, we call them crystalline.]

COLOR.—Colorless, to all colors; white in milky quartz, red in sard, black in onyx, green in prase, yellow in false topaz, etc.

DIAPHANEITY.—Transparent, to opaque; doubly-refractive; transparent in phenocrystalline, or vitreous varieties; translucent in crypto-crystalline chalcidonic varieties; opaque in crypto-crystalline jasper varieties.

ELECTRIC.—Highly electric by friction.

SPEC. GRAV.—2.6.

CHEMICAL PROPERTIES.—In c. t., o. t., in acids and in forceps B. B., without effect; heated on charcoal B. B. with carbonate of soda and potash, fuses, effervesces, and forms a compound sodium silicate or water glass, called also soluble glass;—dissolve in water, filter, in filtrate find the water glass; add HCl acid and obtain precipitated quartz. [Effervescence B. B., caused by escaping CO_2 from the carbonates, shows the acid nature of quartz. The experiment demonstrates the agency of heat and alkali or metallic part in producing silicates.]

CHARACTERISTIC TESTS.—Hardness, lustre, fracture, inertness with reagents; and finally its action B. B. with soda; with crystals, the system indicates the mineral.

VARIETIES.—I. *Crystal*.—Rock crystal, milky, smoky or cairngorm, rose, amethyst, false topaz, cat's eye, etc.

II. *Massive*,—crypto-crystalline and amorphous. —Chalcedony, carnelian, sard, onyx, sardonyx, agate, moss-agate, bloodstone or heliotrope, flint, hornstone, jasper, ferruginous, opal, agatized wood; ordinary massive quartz, sand, sandstone.

Uses.—Glass making, lenses, ornamental stones and ware, mortar and other building cements.

NATURAL HISTORY.—In rocks of all ages. It is disseminated as one of the components of granite and granitoids; also in fissures and segregated masses in metamorphic and igneous rocks; in fusion in igneous rocks it forms, with metallic bases, the feldspars and other silicates, and the feldspathic rocks, such as trap, etc. Physiographically, it constitutes the most enduring features of the Earth's crust, builds new rocks and minerals, and binds anew the old. In volcano, mountain crag and shore contour giving form to the continents and relief to the landscape, it may be called the backbone and rib of the hemispheres, as in the variety, beauty and profusion of its mineral display it has been called "The King of minerals." It ranks easily with calcite as the most educative in our circle of mineralogical study. The word quartz is native to our language, the German of which is *quarz*.

FELDSPAR.—Orthoclase.

FORM.—Massive; crystal, orthoclase is monoclinic, most other feldspars triclinic.

STRUCTURE.—Crystalline; also crystallized (gran-

ular), and finely compact or crypto-crystallized—closely resembling amorphous.

TENACITY.—Tough, medium tough and brittle; felsite, a compact sort, very tough.

COLOR.—Colorless, to all colors; flesh color, light-brown, green, etc.

Lustre on cleavage faces, pearly.

DIAPHANEITY.—Transparent, generally translucent; play of colors, as in labradorite, moonstone, etc.

SPEC. GRAV.—2.57.

CHEMICAL PROPERTIES.—In c. t., in o. t., and with acids, no effect; B. B., infusible, or difficultly on a thin edge. (Albite fuses quite easily and colors flame-bright yellow on account of sodium.)

CHARACTERISTIC TESTS.—Hardness, cleavage, lustre, inertness with reagents.

VARIETIES.—Orthoclase, including sanidin, adularia, moonstone, sunstone and perthite; albite (white) which has also moonstone varieties; clevelandite; labradorite; amazon stone and microcline (green), obsidian, felsite. [The feldspars are grouped under various *clases* beside orthoclase.]

USES.—In brick making, pottery and fine porcelain (it has first to be ground); as gems and ornaments.

NATURAL HISTORY.—The feldspars are largely of metamorphic origin, the product of the union under heat, pressure, water, of quartz with various metallic elements (illustrated B. B. with soda. See *quartz*).

Under the crust, the process is like the chemical reaction in glass making—glass being an artificial silicate as the feldspars are a natural glass colored with metals present. We therefore find feldspar universally, disseminated as one of the components, with quartz, of the granite rocks; in fissures and segregated masses in the rocks; and as the chief part of lavas, trap, pumice, etc.

Physiographically the feldspar by its decay furnishes the muds, clays, etc., enriching the soil with contained metallic elements.

Feld is a field; *spar* a chip or splinter. *Ortho* means straight, and *clase* fracture—referring to the angle of cleavage which is a straight angle (90°)

NOTE.—When, in the heated rocks, by a kind of careful selection quartz unites with potassium, sodium, aluminum, calcium, we have some kind of feldspar with structure and crystal form as set forth above. If the selection is a little more open, a little water, iron and magnesium may be added, and the silicate becomes a mica; but if the door be left wide open, any metal lying about may enter and we have a hornblende.

MICA.—Muscovite.

DIAPHANEITY.—Transparent to opaque; doubly refractive. Biotite nearly opaque.

ELECTRICITY.—Non-conductor, insulator.

SPEC. GRAV.—2.8.

CHEMICAL PROPERTIES.—In c. t., strongly heated,

a little moisture; with acids insoluble (biotite dissolves partly in H_2SO_4); B. B., strongly heated, whitens, fuses on a thin edge.

CHARACTERISTIC TESTS.—Structure, elasticity.

VARIETIES.—Muscovite—potassium mica; biotite,—a magnesium iron mica; lepidolite,—a lithium mica. (Isinglass a common name.)

USES.—Isinglass in stoves; as insulator; for making spangles on textile goods; in fancy paints; ground up for lubricator.

NATURAL HISTORY.—Similar to feldspar, and occurring similarly. In gneiss in which mica is very abundant, the rock is called mica schist. Mica is from *micare*, to shine.

HORNBLLENDE.

HARDNESS.—5 to 6.

FORM.—Massive; crystal, monoclinic, prismatic in general shape.

STRUCTURE.—Crystalline; crystallized, granular, columnar; fibrous in asbestos.

TENACITY.—Sometimes exceedingly tough; may be quite brittle, fragile; is inelastic.

COLOR.—Black or greenish black; if more markedly green, call it pargasite; if light green or gray, call it edenite.

LUSTRE.—Vitreous; shining to dull. The fibrous varieties have silky lustre.

DIAPHANEITY.—Translucent to opaque.

SPEC. GRAV.—Above 3.

CHEMICAL PROPERTIES.—In c. t., in o. t., unaffected; B. B., the mineral fuses.

COMPOSITION.—Silicate of aluminum, magnesium and calcium, with some iron, potassium and sodium.

FORMULA.—Too complex to be conveniently employed.

CLASSIFICATION.—Ternary; bisilicate.

CHARACTERISTIC TESTS.—Hardness, color, weight, structure, and inelasticity when in scales or fine splinters.

VARIETIES.—Common black; pargasite; edenite; asbestos; related to these, and with these put into a group called amphibole, are tremolite, including hexagonite, and actinolite (green radiated).

NATURAL HISTORY.—Found in black rock masses, the crystals in metamorphic and in eruptive rocks.

It is disseminated in hornblendic granites, with or taking the place of mica, recognized by the inelasticity of its scales; similarly we have hornblendic schists, etc.

Hornblende disintegrates by action of atmospheric agencies very rapidly.

FLUORITE.

FORM.—Massive; crystal, isometric, cubic.

COLOR.—Colorless to green, violet, blue, yellow.

DIAPHANEITY.—Translucent to transparent, slightly

doubly-refractive. Some kinds phosphoresce, when gently heated.

Electrified by friction.

SPEC. GRAV.—3.2.

CHEMICAL PROPERTIES.—In c. t., decrepitates, phosphoresces. (Heat small fragments *slightly* in test tube in dark room, see variously colored light emitted by fragments.) Dissolves in H_2SO_4 , giving off hydrofluoric acid which eats (etches) glass—sign of fluorine. B. B., the mineral fuses, coloring the flame reddish yellow,—sign of calcium.

VARIETY.—Fluorite or fluor spar.

USES.—Source of etching fluid; employed as a flux in metallurgy.

NATURAL HISTORY.—Found in metamorphic rocks, but mainly in limestones, and as the veinstone or gangue of ores.

Fluorite is from *fluo*, to flow, referring to its employment as a flux.

APATITE.

FORM.—Massive; crystal, hexagonal.

COLOR.—Green, or brown; red, yellow, blue.

LUSTRE.—Vitreous, shining; sometimes dull; quite resinous.

DIAPHANEITY.—Transparent, translucent, opaque; weakly doubly-refractive; sometimes exhibits pleochroism.

SPEC. GRAV.—3.2.

CHEMICAL PROPERTIES.—In c. t., o. t., whitens; dissolves in acids (with H_2SO_4 white precip. CaSO_4); B. B. difficultly fused, coloring flame reddish yellow (calcium); moistened with H_2SO_4 it gives B. B., a bluish green flame instead of yellow,—sign of phosphoric acid.

VARIETIES.—Ordinary, green and brown; asparagus stone; rock or bone phosphate, guano.

USES.—Source of phosphoric acid, fertilizers.

NATURAL HISTORY.—Found in rocks of all ages, chiefly in metamorphic rocks, in crystallized limestone; probably of animal origin. Calcium phosphate forms in metamorphosis and segregates. Guano found on islands off the coast of Peru. Bone phosphate in Atlantic States, U. S., consisting of animal remains. A distinction should be made, however, between these last and true apatite.

Apatite from *apatao*, Greek, "I deceive." The mineral formerly was taken to be amethyst, aquamarine, fluor spar.

TOPAZ.

FORM.—Massive; crystal, orthorhombic system, prismatic habit.

STRUCTURE.—Amorphous or crystallized; highly crystalline (in crystal form).

CLEAVAGE.—Basal, perfect.

TENACITY.—Massive kinds tough; otherwise brittle.

COLOR.—Colorless; yellow, white, greenish, reddish.

DIAPHANEITY.—Transparent, nearly opaque. Some crystals (being uniaxial), are dichroic,—pink in one direction, yellow in another.

ELECTRICITY.—Gems electric by friction; pyro-electric.

SPEC. GRAV.—3.6.

CHEMICAL PROPERTIES.—In o. t., c. t., with acids, and B. B. in forceps, very inert.

COMPOSITION.—Silicate of aluminum (mostly). [Aluminum silicate and aluminum fluoride.]

FORMULA.— $(\text{AlF})_2\text{SiO}_4$. (Brush.)

CHARACTERISTIC TESTS.—Hardness, cleavage, crystal, and certain special chemical tests.

VARIETIES.—Ordinary massive; crystals of various colors cut as gems; Brazilian rubies (yellow topaz turned pink by heat); "gouttes d'eau" ("drops of water," colorless,—sometimes mistaken for diamonds).

NATURAL HISTORY.—Found in metamorphic rock, sometimes in volcanic.

Topaz, Greek *topazo*, to seek, is an ancient name from an island of the name in the Red Sea. The mineral found on the island, however, as it could be scratched with a file, was probably chrysolite. Though the present mineral appears not to have been known to the ancients, it is held by mineralogists to be correct topaz. False topaz is quartz, oriental topaz is corundum.

CORUNDUM.

FORM.—Massive; crystal, hexagonal system, rhombohedral division.

STRUCTURE.—Crystalline; massive forms are crystallized, to apparent amorphous; sometimes fibrous, radiated.

CLEAVAGE.—Rhombohedral; basal direction perfect.

TENACITY.—Massive sorts, very tough; otherwise quite brittle.

COLOR.—Gray, brownish; of gems, blue, yellow, red, green, purplish; nearly white or colorless.

LUSTRE.—Adamantine; sometimes vitreous; shining, glimmering, dull.

DIAPHANEITY.—Transparent to translucent in gems; opaque in massive sorts.

The crystals are doubly refractive, and being uniaxial are dichroic.

Sapphire seen by transmitted light in one direction transverse to its optical axis is deep blue; in another direction (on the other lateral axis) is green. Ruby is orange and carmine in two different directions.

ELECTRICITY.—Gems are electric by friction.

SPEC. GRAV.—4.

CHEMICAL PROPERTIES.—In c. t., o. t., etc., without effect; for a metallic oxide it is surprisingly inert. Pulverized and treated upon charcoal with cobaltic nitrate, gives blue color, sign of aluminum.

CHARACTERISTIC TESTS.—Hardness, inertness, weight; with gems, double refraction, dichroism, color.

VARIETIES:—Massive, corundum, emery; gems, sapphire (blue); ruby (red); topaz (yellow); emerald (green); amethyst (violet); asteria or star sapphire. With the names, oriental is employed, as oriental amethyst.

USES.—The massive is ground to be used as an abrasive, being too valuable as such to be consumed as a source of aluminum. (Cryolite and beauxite, a hydrous oxide of the metal are sources of Al.) Emery wheels; bearings for fine watches and instruments; gems and ornaments.

NATURAL HISTORY.—Found in metamorphic rocks, —granites and crystallized limestones. The word sapphire is found in ancient Hebrew,—JOB, O. T., 26th Chapter,—and in Greek, and probably meant *lapis lazuli* stone. The blue Al_2O_3 (sapphire) was anciently called *hyacinth*, a name now applied to zircon gems. The word sapphire at one time included all the gems, but now refers only to the blue. Spinel rubies, scarlet; and a red spinel ruby called also Balas ruby ($\text{MgO} \cdot \text{Al}_2\text{O}_3$), must be distinguished from true ruby, Al_2O_3 ; as must also the garnets; also the beryl emerald from the oriental. The word corundum is from Hindoo *kurand*.

DIAMOND.

FORM.—Massive; crystal, isometric,—found in octahedrons and dodecahedrons. Massive has two kinds,—bort and carbonado.

STRUCTURE.—Gem, crystalline; bort is radiated, semi-crystallized to amorphous; carbonado, crypto-crystalline or amorphous.

CLEAVAGE.—Gem, octahedral and tetrahedral, perfect; in other forms wanting.

FRACTURE.—Conchoidal.

TENACITY.—Weak in gems, brittle; hard; in other forms tough.

COLOR.—Colorless to white and every pale tint of other colors, a favorite being bluish; of bort, gray to blackish; of carbonado, black.

STREAK.—Uncolored, or of diminished color.

LUSTRE.—Adamantine, brilliantly shining; bort, greasy; carbonado, resinous.

DIAPHANEITY.—Gem, transparent; singly refractive, being of isometric system; bort, translucent; carbonado, opaque.

TOUCH.—Smooth, harsh.

Electric by friction.

WEIGHT.—Rather heavy.

SPEC. GRAV.—Gem, 3.52; bort, 3.5; carbonado, 3.25.

CHEMICAL PROPERTIES.—Unaffected by tests, but powdered and mingled with KClO_3 burns the same

as graphite, giving CO_2 ,—which proves diamond to be carbon.

CHARACTERISTIC TESTS.—Lustre, refractive index, single refraction, hardness, conductivity to heat, weight; chemical test by burning (bort and carbonado).

VARIETIES.—The gem; bort; carbonado,—called also “black diamond” and even “anthracite.”

USES.—Gems, ornaments; in glass cutters, in drills, saws. Diamonds, like other very hard precious stones, were originally worn in the rough after chipping.

Diamond cutting with its own powder was invented in 1476. “The natural lustre at the front reflecting surface of the diamond is enhanced by so cutting the back of the diamond, that, by reflection at the rear surface, the light that enters the gem at the front is brought out again at the front. And as this reflected light has also been dispersed by the high dispersive power of the diamond so as to display the several colors of the spectrum, the diamond thus acquires the fire and brilliancy characteristic of the gem.” [“Public School Mineralogy” in preparation.]

Most anciently the gems were obtained in India, later in Brazil, and recently in South Africa, whence last up to 1886, \$250,000,000 worth were taken. Their origin, according to Dana, is connected with volcanic heats and outflow. Diamond from Greek

adamas, the "unsubduable;" it yielded to no reagent, especially the ancient one of fire.

NOTE on gems mentioned.—Strass, or paste, is a glass of fine quality, made, colored and cut to imitate gems. The precious stones are heavier than glass (Spec. Grav. 2.5), better conductors of heat, harder, and capable of finer polish and lustre. Paste, being amorphous, has single refraction; paste gems, being of low refractive index are set with metallic backing to increase reflection.

Lay a paste and a diamond of equal temperature upon the hand; the diamond, because a better conductor, feels cooler; breathe upon both,—for the same reason the diamond collects the most moisture.

The diamond, being of the isometric system and hence having single refraction is distinguished from similar appearing corundum gems, by the double refraction of the latter, and for the same reason from the colorless topaz (*gouttes d'eau*). The last is also known by its pyro-electricity, becoming electric if heated.

The red corundum gems are distinguished from the garnet and the spinel rubies by the single refraction of the latter, which are both of the isometric system.

The oriental ruby is very rare and several times more valuable than a diamond of the same weight. The spinel ruby is found with the oriental, and many supposed rubies are spinels. The composition of the spinel is nearly that of the corundum gem having magnesium in place of some of the corundum, and a little chromium which gives it its red color.

AZURITE.—*Malachite*.

FORM.—Crystal, monoclinic; massive, botryoidal.

STRUCTURE.—Crystalline, fibrous, amorphous.

COLOR.—Azurite, blue; malachite, green.

STREAK.—A paler color.

LUSTRE.—Vitreous, shining; silky or velvety; sometimes dull.

SPEC. GRAV.—Azurite, 3.8, malachite, 4.

CHEMICAL PROPERTIES.—In c. t., o. t., water driven off; fragment blackness (changed from carbonate to black oxide). Dissolves in HCl acid giving off CO_2 . B. B., fuses, colors the flame green (copper), and on charcoal gives bead of malleable copper.

COMPOSITION.—Hydrous copper carbonate, azurite having greater proportion of carbonate.

FORMULA.—Azurite, $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$, malachite, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$.

CHARACTERISTIC TESTS.—Color, acid and B. B. test.

USES.—Ornaments; ornamental wares, ore of copper.

NATURAL HISTORY.—The copper mines of the world are extremely local in distribution, and are generally found associated with igneous rocks; the ores are native, chalcopyrite, chalcocite, cuprite beside the carbonates. The last were originally sulphides, being changed to carbonates in the upper part of the deposits. The greatest mines in their order are in Montana, Michigan, Arizona. The United States lead in production of copper.

The ores are very commonly associated with silver, gold, iron, etc. The use of copper, as it is found native, dates from remote antiquity. Bronze, made

of copper and tin; and brass of copper and zinc, are very ancient alloys.

The word copper comes from Cyprus, the island of eastern Mediterranean Sea, containing a famous ancient mine.

Azurite means blue; malachite is from the green *malache* or mallows.

CRYOLITE.

FORM.—Massive; crystal, monoclinic.

DIAPHANEITY.—Translucent to transparent; more translucent when wet,—hence name cryolite, ice-stone.

SPEC. GRAV.—3.

CHEMICAL TESTS.—In c. t., fuses; in o. t., sets free hydrofluoric acid which etches the glass.—sign of fluorine; B. B., melts easily, colors flame yellow (sign of sodium); B. B., on charcoal with cobaltic nitrate gives blue color (sign of aluminum).

CHARACTERISTIC TESTS.—Hardness, structure, chemical test.

VARIETY.—Cryolite.

USES.—A source of aluminum; the metal extracted by the electrical process.

NATURAL HISTORY.—Found in veins in granitic rocks, notably at Evigtuk, Greenland, associated with galena, pyrite, chalcopyrite, siderite and sphalerite,—with lead, copper, iron, zinc.

SPHALERITE

FORM.—Massive; crystal, isometric system, tetrahedral.

STRUCTURE.—Amorphous; crystallized, granular; often markedly crystalline.

COLOR.—Pure, it is white; with iron, manganese, it is brown, black.

LUSTRE.—Resinous; crystals somewhat adamantine.

SPEC. GRAV.—4.

CHEMICAL TESTS.—Heated in c. t., coating of sulphur sublimes; in o. t., sulphur burns; dissolves in HCl acid giving odor of hydrogen sulphide; dissolves in nitric acid forming globule of S. [The last two are sign of sulphide.] B. B., fuses with difficulty and on charcoal gives a coating yellow when hot, white when cold,—sign of zinc.

CHARACTERISTIC TESTS.—Hardness, structure, white coating on charcoal.

VARIETIES.—Ordinary; called also zinc blende, black jack; stanniferous, containing tin; ferriferous (iron).

USES.—Chief ore of zinc; metal extracted by roasting to remove sulphur, then by carbon, to remove oxygen; closed furnace or retort to prevent volatilization of zinc.

NATURAL HISTORY.—Found in rocks of all ages; mostly in large segregated masses in limestone along with ores of lead, iron, copper, silver. Zinc is known

only in modern times as a metal, though brass, an alloy, was made anciently, by employing its ore to mingle with copper ore.

The word sphalerite means treacherous; the black jack or blende being quite easily taken for galena.

Other ores are zincite, oxide, red with oxide of manganese; troostite, silicate of zinc; smithsonite, carbonate of zinc.

SUPPLEMENTARY EXPERIMENTAL WORK.

MODEL FOR BLANKS.

.....
(Date of study,..... Time employed,.....)

Hardness

Form

.....
Structure

.....
Cleavage

.....
Fracture

Tenacity.....

.....
Color

Streak

Lustre

Diaphaneity

.....
Touch

Magnet. Electricity

Weight, Sp. G.

Chemical Properties.....

.....

.....

.....

Composition

Formula

Classification

Characteristic tests

Varieties.....

Uses ; Element of Value, how extracted ; Natural History.

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MODEL FOR ROCKS.

Granite.

Sandstone.

Limestone.

MODEL FOR METALS.

Copper.

Brass.

Bronze.

Tin.

Lead.

Zinc.

Iron.

Steel.

TOPICAL REFERENCES TO PHYSICAL
GEOGRAPHY.

